Week 1

1. What is Physiology?

Physiology is the study of how the body works.

Anatomy is what the body looks like.
Physiology is what the body does.

There are two ways to explain the body:

- Teleological: explains the purpose (why something happens)
- Mechanistic: explains the cause and effect (how it happens step-by-step)

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2. Levels of Organization

The body is organized from smallest level to larger levels:

- Molecules build cells
- Cells build tissues
- Tissues build organs
- Organs build organ systems
- An organism is made up of multiple organ systems working together.

Cells are the basic unit of life.

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3. Matter and Elements

Everything in the body is made of matter.

Matter is anything that takes up space and has mass.

Matter is made of elements.

The main elements in the body are:

- Carbon
- Hydrogen
- Oxygen
- Nitrogen

Other important elements include iron (needed for hemoglobin).

These are the building blocks of life.

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4. Atoms and Structure

Atoms are the smallest unit of an element. Atoms have:

- Protons (positive, in nucleus)
- Neutrons (no charge, in nucleus)
- Electrons (negative, outside nucleus)

Key idea:

- Atomic number = number of protons
- Mass number = protons + neutrons

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5. Isotopes and Radioactivity

Isotopes are atoms of the same element with different numbers of neutrons.

They behave the same chemically but have different masses.

Example: carbon isotopes

- Carbon-12
- Carbon-13
- Carbon-14 (radioactive) (Also used in radiocarbon dating.)

Some isotopes are unstable and release energy. This is called radioactivity.

Radioactivity is used in medicine for:

- Scans
- Cancer treatment
- Sterilization

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6. Chemical Bonds

Atoms join together using bonds, These bonds build all biological molecules.:

- Ionic bonds: electrons are transferred
- Covalent bonds: electrons are shared
- Hydrogen bonds: weak attraction between molecules

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7. Water and Its Importance

Water is essential for life, as it regulates body temperature and is essential for biochemical reactions.

It has special properties because it is polar.

Key properties:

- It dissolves many substances
- It sticks to itself (cohesion)
- It sticks to other surfaces (adhesion)
- Ice floats because it is less dense

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8. Acids, Bases, and pH

pH measures how acidic or basic something is, it ranges from 0 to 14

- Acid = below 7 (lemon juice, battery acid)
- Neutral = 7 (pure water)
- Base = above 7 (bleach, baking soda)

The body keeps blood around pH 7.4 using buffers. Keeping it stable for survival.

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9. Organic Molecules

There are four main types of biological molecules:

- Carbohydrates: quick energy
- Lipids: long-term energy and protection
- Proteins: build and repair body structures
- Nucleic acids (DNA and RNA): store genetic information

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10. Carbohydrates

Carbohydrates are the body's main energy source.

They can be:

- Simple sugars (one or two units)
- Complex sugars (many units like starch or glycogen)

They are broken down to release energy quickly.

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11. Lipids

Lipids are fats.

They:

- Store energy long-term
- Protect organs
- Help form cell membranes
- Make hormones

Types:

- Saturated fats: solid
- Unsaturated fats: liquid
- Trans fats: unhealthy

HDL (high-density lipoprotein) removes cholesterol, LDL (low-density lipoprotein) builds it up.

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12. Proteins

Proteins are made of amino acids.

They are responsible for:

- Building tissues
- Repairing damage
- build/repair Enzymes and hormones

Protein structure determines function:

- Sequence → folding → shape → function

If shape changes (heat or pH), the protein stops working.

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13. DNA and RNA

DNA stores genetic instructions.

RNA helps use those instructions to make proteins.

Difference:

- DNA = double strand, has thymine
- RNA = single strand, has uracil

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14. ATP (Energy)

ATP is the energy “currency” of the cell.

When ATP loses a phosphate, energy is released.

ATP becomes ADP after energy is used.

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15. Cell Structure

- Aerobic respiration = uses oxygen → lots of energy (ATP)
- Anaerobic respiration = no oxygen → less energy + lactic acid

All cells have:

- Cell membrane (controls what enters and leaves)
- Cytoplasm (fluid inside)
- Nucleus (control center)

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16. Cellular Respiration

Cells make energy from glucose using oxygen.

Steps:

- Glycolysis
- Transition reaction
- Citric acid cycle
- Electron transport chain

This produces ATP, which powers the body.

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17. Membrane Transport

Cells move substances in and out:

Passive transport = no energy needed

- Diffusion
- Osmosis

Active transport = needs energy (ATP)

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18. Cell Junctions

Cells connect in three ways:

- Desmosomes: hold cells together
- Tight junctions: seal spaces
- Gap junctions: allow communication

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19. Body Fluids

Cells communicate using:

- Hormones (chemical signals)
- Nervous system (electrical signals)
- Gap junctions (direct cell-to-cell communication)

Body fluids are divided into:

- Intracellular fluid: inside cells
- Extracellular fluid: outside cells

Extracellular includes blood plasma and fluid around cells.

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20. Homeostasis

Homeostasis means keeping the internal body stable within a range.

It does NOT mean constant values.

Examples:

- Temperature changes slightly
- Blood sugar rises after eating
- Blood pressure changes constantly

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21. Homeostatic Control System

Three parts:

- Sensor: detects change
- Control center: processes information
- Effector: fixes the problem

There are two types:

- Intrinsic: local control
- Extrinsic: nervous and hormonal control

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22. Feedback Systems

- Negative feedback: reverses change to restore balance
- Positive feedback: amplifies change (example: childbirth)
- Feedforward: prepares before change happens

Week 2

1. What is the Male Reproductive System?
Definition

- The **male reproductive system** is a group of organs that **make sperm**, **make testosterone**, and **deliver sperm**.

Main Jobs

- Make **sperm** (male sex cells).
- Make **testosterone** (male hormone).
- Deliver sperm during reproduction.

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2. Main Organs
Testes (Testicles)
Definition

- Two organs making sperm and testosterone.

Jobs

- Make sperm.

- Make testosterone.

Remember

- Testes = **male gonads** (organs that make sex cells and hormones).

Epididymis

Definition

- A long, coiled tube on top of each testis.

Jobs

- Sperms grow and mature here.
- Stores sperm until needed.

Think

- **Sperm "school."** They learn how to swim here.

Vas Deferens

Definition

- A tube that carries sperm.

Job

- Moves sperm from the epididymis to the urethra.

Seminal Vesicles

Definition

- Glands that add sugary fluid to sperm.

Jobs

- Add **fructose (sugar)**.
- Give sperm energy.
- Make most of the semen.

Semen

- The liquid that carries sperm.

Prostate Gland

Definition

- A gland that adds protective fluid to semen.

Jobs

- Helps sperm stay alive.
- Protects sperm from acid.

Bulbourethral (Cowper's) Glands

Definition

- Small glands that release mucus before ejaculation.

Jobs

- Lubricate the urethra.
- Wash away leftover acidic urine.

Penis

Definition

- The organ that releases semen.

Job

- Delivers sperm.

Urethra

Definition

- Tube that carries urine and semen out of the body.

Sperm Pathway

Testes

⬇️

Epididymis

⬇️

Vas Deferens

⬇️

Urethra

⬇️

Penis

Memory Trick

Make → Mature → Move → Out

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3. Spermatogenesis (Making Sperm)

Definition

- **Spermatogenesis** = making sperm.

Where?

- Inside tiny tubes in the testes called **seminiferous tubules**.

Starts

- At puberty.

Continues

- For most of a man's life.

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4. How Sperm Are Made

Spermatogonium

- The **starter cell**.

⬇️

Primary Spermatocyte

- Get ready to divide.

⬇️

Meiosis I

- Chromosome number is cut in half.

⬇️

Secondary Spermatocyte

- Half the chromosomes.

⬇️

Meiosis II

- Divided again.

⬇️

Spermatid

- An immature sperm.

⬇️

Spermatozoa

- A fully grown sperm.

Important

- **1 starter cell makes 4 sperm.**

Memory Trick

One becomes Four

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5. Parts of a Sperm

Head

Contains:

- DNA.
- Acrosome (enzymes that help break into the egg).

Midpiece

Contains:

- Mitochondria.

Job

- Makes ATP (energy).

Tail

Job

- Helps sperm swim.

Memory Trick

- **Head = Think**
- **Middle = Power**
- **Tail = Swim**

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6. Hormones That Control Sperm

Brain → Testes

Hypothalamus

⬇️

GnRH

⬇️

Pituitary Gland

⬇️

FSH + LH

⬇️
Testes

FSH
Job

- Helps make sperm.

LH
Job

- Tell the testes to make testosterone.

Testosterone
Jobs

- Helps make sperm.
- Deep voice.
- Facial hair.
- Bigger muscles.

Sertoli Cells
Job

- Feed and protect growing sperm.

They also make **Inhibin**.

Inhibin
Job

- Slows down sperm production when enough sperm have been made.

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7. Negative Feedback
What is it?

- The body slows things down when there is enough.

Example:

- High testosterone → brain makes less LH.
- High inhibin → brain makes less FSH.

Purpose

- Keeps hormone levels balanced.

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8. Male Puberty Changes
Testosterone causes:

- Facial hair.
- Deeper voice.
- Bigger muscles.
- Wider shoulders.
- Growth of reproductive organs.

Male Summary

- Testes → make sperm + testosterone.
- Epididymis → sperm mature.
- Vas deferens → moves sperm.
- FSH → makes sperm.
- LH → makes testosterone.
- Testosterone → male body changes.
- Inhibin → slows FSH.

Female Reproductive System

1. What is the Female Reproductive System?

Definition

- A group of organs that **make eggs**, **make hormones**, and **help grow a baby**.

Main Jobs

- Make eggs.
- Make estrogen.
- Make progesterone.
- Receive sperm.
- Grow and protect a baby during pregnancy.

Memory Trick

Female = Make + Receive + Grow

---

2. Main Organs

Ovaries

Definition

- Two organs that make eggs and hormones.

Jobs

- Make eggs.
- Make estrogen.
- Make progesterone.

Fallopian Tubes

Definition

- Tubes carrying the egg to the uterus.

Important

- This is **usually where sperm meets the egg**.

Fertilization

Definition

- When the sperm joins the egg.

Uterus (Womb)

Definition

- The place where a baby grows.

Endometrium

Definition

- The soft lining of the uterus.

Jobs

- Gets thicker every month.
- Feeds a baby if pregnancy happens.
- Falls off during a period if there is no pregnancy.

Cervix

Definition

- The doorway between the uterus and vagina.

Vagina

Definition

- A muscular tube.

Jobs

- Receives sperm.
- Birth canal.
- Let menstrual blood leave the body.

Egg Pathway

Ovary

⬇️

Fallopian Tube

⬇️

Uterus

⬇️

Cervix

⬇️

Vagina

Memory Trick

Make → Travel → Home

---

3. Oogenesis (Making Eggs)

Definition

- **Oogenesis** = making eggs.

Where?

- Ovaries.

Important

- Girls are born with all their immature eggs.
- Only about **400 eggs** are released during life.

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4. How Eggs Develop

Primary Oocyte

- Immature egg present from birth.

⬇️

Meiosis I

⬇️

Secondary Oocyte

- Egg released during ovulation.

⬇️

Ovulation

- The egg leaves the ovary.

⬇️

If sperm enters

Meiosis II finishes.

⬇️

Ovum

- Fully mature egg.

Important

- No sperm = egg never fully finishes developing.

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5. Ovarian Cycle

Follicular Phase (Days 1–13)

- FSH grows the egg.
- Estrogen increases.

Ovulation (Day 14)

- High estrogen causes a big LH surge.
- LH releases the egg.

Luteal Phase (Days 15–28)

- Corpus luteum forms.
- Makes progesterone.
- Keeps the uterus ready for a baby.

If no pregnancy:

- Corpus luteum disappears.
- Progesterone drops.
- Period starts.

Memory Trick

Grow → Release → Prepare

---

6. Menstrual Cycle

Menstrual Phase (Days 1–5)

- Uterus lining sheds.
- Period happens.

Proliferative Phase (Days 6–13)

- Estrogen rebuilds the lining.

Secretory Phase (Days 15–28)

- Progesterone makes the lining thick.
- Uterus gets ready for a baby.

Memory Trick

Shed → Grow → Prepare

---

7. Hormones

FSH

Job

- Grow the egg.

LH

Job

- Releases the egg (ovulation).

Estrogen

Jobs

- The female body changes during puberty.
- Rebuilds the uterus lining.

Progesterone

Jobs

- Keeps the uterus lining thick.
- Helps support pregnancy.

---

8. Feedback

Most of the Month

- Estrogen and progesterone tell the brain to slow hormone release.

Before Ovulation

- High estrogen tells the brain to release **a lot of LH**.

LH Surge = Ovulation

Memory Trick

High Estrogen = Huge LH

---

9. Pregnancy

hCG

Definition

- A hormone made by the tiny embryo.

Jobs

- Keeps progesterone high.
- Stop the period.

- Helps keep the pregnancy going.

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10. Menopause
Definition
- When periods stop permanently because the ovaries stop releasing eggs.

Usually Happens
- Around **45–55 years old**.

Changes
- No more ovulation.
- Less estrogen.
- Less progesterone.
- Periods stop.

Memory Trick
Menopause = Ovaries Retire

Week 3

16.1 — ENDOCRINE GLANDS AND HORMONE ACTION

Learning Objective: Distinguish between neurotransmitters and hormones.

- Neurotransmitters are chemical signals released by neurons. They cross a synapse and act on nearby target cells. Their effects are rapid and usually short-lived.

- **Hormones:** Chemical messages made by **endocrine glands** that travel through the **bloodstream to the body**; **slow + long-lasting**.

- Both systems use chemical signals, act through receptors, respond to changes, and help maintain homeostasis.

- Endocrine glands are ductless. As they release hormones directly into the blood.

- Exocrine glands use ducts to deliver substances to a body surface or body cavity.

- Example: salivary glands release saliva through ducts into the mouth.

- Hypothalamus: links the nervous and endocrine systems and controls the pituitary.

- Pituitary gland: regulates growth, water balance, reproduction, and other endocrine glands.

- Thyroid gland: regulates metabolic rate and contributes to blood-calcium regulation.

- Parathyroid glands: regulate blood calcium.

- Adrenal glands: regulate stress responses, blood pressure, and water–salt balance.

• Pancreas: regulates blood glucose.

• Testes and ovaries: produce sex hormones and regulate reproduction.

• Thymus: supports T-lymphocyte development.

• Pineal gland: produces melatonin and helps regulate the sleep–wake cycle.

• Other hormone-producing organs include the kidneys, heart, gastrointestinal organs, and adipose tissue.

• Peptide hormones are made of peptides, proteins, or glycoproteins. They cannot cross the plasma membrane.

• They bind to receptors on the cell membrane and commonly activate a second messenger such as cyclic AMP (cAMP).

• The hormone is the first messenger. cAMP carries the message inside the cell and can activate an enzyme cascade.

• Example: epinephrine can activate cAMP, causing glycogen to be broken down into glucose.

• Steroid hormones are derived from cholesterol and are lipid-soluble. They cross the plasma membrane and bind to receptors inside the cell.

• Hormone binds the receptor → tells the cell to make new proteins.

• Peptide hormones turn things **on**; steroid hormones change the cell's **instructions**.

16.2 — HYPOTHALAMUS AND PITUITARY GLAND

• The hypothalamus is the major link between the nervous and endocrine systems.

It helps regulate body temperature, water–salt balance, the internal environment, and autonomic nervous-system activity.

• It controls the posterior pituitary by producing ADH and oxytocin.

• It controls the anterior pituitary by producing, releasing and inhibiting hormones.

• Because it receives nervous information and produces hormones, it is a neuroendocrine organ.

Posterior Pituitary

- **ADH & oxytocin** are made in the hypothalamus, stored in the posterior pituitary, and released into the blood.
- **ADH** increases water reabsorption by the kidneys to reduce urine and prevent dehydration.
- **High blood concentration** triggers ADH release; negative feedback restores normal levels.
- **Low ADH** causes diabetes insipidus with excessive dilute urine and dehydration.
- **Oxytocin** causes uterine contractions and milk letdown.
- **Childbirth** uses positive feedback: contractions → more oxytocin → stronger contractions until birth.
- **Memory: ADH = Adds water back; Oxytocin = Contractions & milk letdown.**

Anterior Pituitary

- The **hypothalamus** controls the anterior pituitary through a **portal system**.
- **TSH** stimulates the thyroid to release thyroid hormones.
- **ACTH** stimulates the adrenal cortex to produce cortisol.
- **FSH** promotes egg development and sperm production.
- **LH** regulates reproduction and sex hormone production.
- **Prolactin** stimulates milk production.
- **MSH** affects skin pigmentation (minimal role in humans).
- **GH** promotes body growth, protein synthesis, fat metabolism, and IGF-1 production.
- **Memory: Prolactin = Produces milk; Oxytocin = Releases milk.**

Growth Hormone Disorders

- **Low GH in childhood** → Pituitary dwarfism (short stature, normal proportions).
- **High GH in childhood** → Gigantism (excessive height).
- **High GH in adulthood** → Acromegaly (enlarged hands, feet, and face).
- **Memory: Low GH child = Dwarfism; High GH child = Gigantism; High GH adult = Acromegaly.**

16.3 – Thyroid & Parathyroid

Hormones

- **The thyroid gland** produces **T3, T4, and calcitonin** to regulate metabolism and blood calcium.
- **T3** contains **3 iodine atoms**, while **T4** contains **4 iodine atoms**.
- **T3 and T4** increase metabolic rate and support normal growth and development.
- **Iodine** is required by the thyroid gland to produce T3 and T4.

- **Calcitonin** lowers blood calcium by promoting calcium storage in bones and reducing osteoclast activity.
- **The parathyroid glands** produce **PTH (parathyroid hormone)**.
- **PTH** raises blood calcium by acting on bone, kidneys, vitamin D, and the intestines.

Blood Calcium Homeostasis

- **High blood calcium** causes calcitonin release, lowering calcium back to normal by negative feedback.
- **Low blood calcium** causes PTH release, raising calcium back to normal by negative feedback.
- **Calcitonin and PTH** have opposite effects to maintain blood calcium homeostasis.

Disorders

- **Iodine deficiency** reduces T3/T4 production and may cause an enlarged thyroid (goiter).
- **Hypothyroidism** causes low metabolism, fatigue, weight gain, and cold intolerance.
- **Hyperthyroidism** causes high metabolism, weight loss, nervousness, and rapid heartbeat.
- **Hypoparathyroidism** lowers blood calcium and may cause tetany (muscle spasms).
- **Hyperparathyroidism** removes too much calcium from bone, causing osteoporosis and kidney stones.
- **Memory: Hypo = Too slow; Hyper = Too fast.**

16.4 – Adrenal Glands

Hormones

- **The adrenal glands** sit above the kidneys and contain an outer cortex and inner medulla.
- **The adrenal medulla** produces epinephrine and norepinephrine for the fight-or-flight response.
- **Epinephrine and norepinephrine** increase heart rate, blood pressure, blood glucose, and muscle energy.
- **The adrenal cortex** produces cortisol, aldosterone, and small amounts of sex hormones.
- **Cortisol** raises blood glucose, breaks down fats and proteins, and reduces inflammation.
- **Aldosterone** causes the kidneys to retain sodium and water while excreting potassium.
- **Memory: Medulla = Emergency response; Cortex = Long-term stress response.**

Stress Response

- **Hypothalamus → ACTH → Adrenal cortex → Cortisol** during long-term stress.
- **Cortisol** provides energy by increasing blood glucose and promoting fat and protein metabolism.
- **Cortisol** also suppresses inflammation and parts of the immune response.
- **The medulla** acts quickly, while **the cortex** responds more slowly but lasts longer.

Glucocorticoids vs Mineralocorticoids

- **Glucocorticoids (cortisol)** mainly regulate blood glucose and long-term metabolism.
- **Mineralocorticoids (aldosterone)** mainly regulate sodium, potassium, water, and blood pressure.
- **Memory: Glucocorticoids = Glucose; Mineralocorticoids = Minerals.**

RAAS & ANH

- **Low blood pressure or sodium** causes the kidneys to release renin.
- **Renin** starts a pathway that produces angiotensin II.
- **Angiotensin II** narrows blood vessels and stimulates aldosterone secretion.
- **Aldosterone** raises blood volume and pressure by retaining sodium and water.
- **ANH** is released by the heart when blood volume becomes too high.
- **ANH** removes sodium and water to reduce blood volume and pressure.
- **Memory: Aldosterone saves sodium; ANH removes sodium.**

Disorders

- **Addison's disease** results from too little adrenal cortex hormone production.
- **Cushing's syndrome** results from excessive cortisol production.

16.5 – Pancreas & Blood Glucose

Pancreas

- **The pancreas** functions as both an endocrine gland and an exocrine gland.
- **The exocrine pancreas** releases digestive enzymes into the small intestine.
- **The endocrine pancreas** contains the pancreatic islets (Islets of Langerhans).
- **Alpha (A) cells** produce glucagon.
- **Beta (B) cells** produce insulin.
- **Delta (D) cells** produce somatostatin.

Insulin & Glucagon

- **Insulin** is released when blood glucose becomes high, usually after eating.
- **Insulin** moves glucose into cells and stores excess glucose as glycogen.
- **Insulin** lowers blood glucose back toward normal.
- **Glucagon** is released when blood glucose becomes low, usually between meals.
- **Glucagon** causes the liver to release stored glucose into the bloodstream.
- **Glucagon** raises blood glucose back toward normal.
- **Memory: Insulin puts glucose into cells; Glucagon puts glucose into blood.**

Diabetes

- **Diabetes mellitus** is the inability to properly regulate blood glucose levels.
- **Type 1 diabetes** occurs when little or no insulin is produced by the pancreas.
- **Type 1 diabetes** requires lifelong insulin treatment to control blood glucose.
- **Type 2 diabetes** occurs when body cells become resistant to insulin.
- **Memory: Type 1 = Missing insulin; Type 2 = Insulin resistance.**

16.6 – Other Endocrine Glands

Reproductive Hormones

- **The testes** produce testosterone for male development, sperm production, and secondary sex characteristics.
- **Testosterone** increases muscle mass, body hair, and deepens the voice.
- **The ovaries** produce estrogen, progesterone, and small amounts of testosterone.
- **Estrogen** supports female development, reproduction, and secondary sex characteristics.
- **Estrogen and progesterone** regulate the menstrual cycle, pregnancy, and breast development.
- **GnRH, FSH, and LH** control the gonads through negative feedback mechanisms.

Melatonin

- **The pineal gland** produces melatonin to regulate the sleep-wake cycle.
- **Melatonin** increases at night and promotes feelings of sleepiness.
- **Light exposure** decreases melatonin production during the daytime.
- **Memory: Melatonin = Moon hormone that promotes sleep.**

EPO

- **Low blood oxygen** causes the kidneys to release erythropoietin (EPO).
- **EPO** stimulates red bone marrow to produce more red blood cells.
- **Negative feedback** reduces EPO release once oxygen levels return to normal.
- **Memory: Low O_2 → EPO → More red blood cells.**

Other Hormones

- **The thymus** produces thymosins that help T lymphocytes mature during childhood.
- **Leptin** acts on the hypothalamus to signal fullness after eating.
- **Growth factors** stimulate cell growth, repair, and cell division.
- **Prostaglandins** act locally to promote pain, inflammation, fever, and uterine contractions.
- **Aspirin** reduces pain and fever by decreasing prostaglandin production.
- **Memory: Thymus = T cells; Leptin = Full; Prostaglandins = Local actions.**

16.7 – Hormones & Homeostasis

External Changes

- **The nervous system** responds rapidly to changes in the external environment.
- **Sensory receptors** detect changes and send information to the central nervous system.
- **The CNS** processes the information and decides the correct response.
- **Nerves** activate muscles or glands to carry out the response.
- **Example:** A blink reflex protects the eyes from approaching objects.
- **Memory: Sense → Process → Respond.**

Internal Changes

- **Internal regulation** uses reflexes, hormones, the hypothalamus, and the autonomic nervous system.
- **Low blood pressure** is detected by baroreceptors located in major arteries.
- **The medulla** increases heart rate and constricts blood vessels to restore pressure.
- **Negative feedback** returns blood pressure toward its normal level.
- **Memory: Low BP → Baroreceptors → Medulla → Heart ↑ & Vessels ↓.**

Water–Salt Balance

- **Sweating** causes the body to lose both water and sodium.
- **Aldosterone** helps the kidneys retain sodium so water is also retained.
- **ADH** increases water reabsorption and reduces water loss in urine.
- **Alcohol** inhibits ADH, increasing urine production and causing dehydration.
- **Memory: Aldosterone saves salt; ADH saves water.**

Reproduction

- **The hypothalamus** controls the pituitary gland by releasing regulatory hormones.
- **FSH and LH** regulate gamete production and sex hormone secretion.

- **Nervous signals** also control muscle contractions involved in reproduction.
- **Oxytocin** strengthens uterine contractions through positive feedback during childbirth.

Nervous & Endocrine Integration

- **The nervous system** provides fast, short-term responses to changing conditions.
- **The endocrine system** provides slower, longer-lasting regulation of body functions.
- **The hypothalamus** links both systems by controlling hormones and autonomic functions.
- **The neuroendocrine system** is the coordinated action of the nervous and endocrine systems.
- **Memory: Nervous = Fast; Endocrine = Long-lasting; Hypothalamus = Connection.**

WEEK 4
5.1 — Overview of the Cardiovascular System

Main Idea

- The cardiovascular system is the body's transportation system.
- The heart is a muscular pump that creates pressure to move blood.
- Blood vessels are tubes that carry blood throughout the body.
- Arteries carry blood away from the heart.
- Veins carry blood toward the heart.
- Capillaries are tiny vessels where exchange with body cells occurs.

Main Functions

- Blood delivers oxygen and nutrients to cells.
- Blood removes carbon dioxide and metabolic wastes from cells.
- Blood transports hormones and immune cells.
- The cardiovascular system helps regulate body temperature.
- The cardiovascular system helps maintain blood pH.
- The cardiovascular system helps maintain water and electrolyte balance.

Lymphatic System

- The lymphatic system collects excess tissue fluid.
- The lymphatic system returns excess fluid to the bloodstream.
- Returning excess fluid prevents swelling called edema.

Remember: Heart = pump; arteries = away; veins = toward; capillaries = exchange.

5.2 — Types of Blood Vessels

Arteries

- Arteries carry blood away from the heart.
- Arteries usually carry oxygen-rich blood.
- Arteries have thick, muscular, elastic walls.
- Arteries have high blood pressure.
- Pulmonary arteries are an exception because they carry oxygen-poor blood.

Capillaries

- Capillaries are the smallest blood vessels.
- Capillary walls are only one cell thick.
- Capillaries are the main site of exchange.
- Oxygen and nutrients move from the blood into cells.
- Carbon dioxide and wastes move from cells into the blood.
- Precapillary sphincters control blood entering capillaries.

Veins

- Veins carry blood toward the heart.
- Veins have thin walls because blood pressure is low.
- Veins contain valves that prevent blood from flowing backward.
- Veins store about 70% of the body's blood.
- Pulmonary veins are an exception because they carry oxygen-rich blood.

Remember: Arteries = high pressure; capillaries = exchange; veins = valves.

5.3 — The Heart

Four Chambers

- The four heart chambers are the right atrium, right ventricle, left atrium, and left ventricle.
- The right side of the heart pumps blood to the lungs.
- The left side of the heart pumps blood to the body.
- The left ventricle has the thickest muscle because it pumps blood throughout the body.

Heart Valves

- The tricuspid and mitral valves are atrioventricular valves.
- The pulmonary and aortic valves are semilunar valves.
- Heart valves prevent blood from flowing backward.
- Heart valves keep blood moving in one direction.

Blood Flow

- Blood travels from the body to the vena cava.
- The vena cava carries blood into the right atrium.
- The right atrium sends blood to the right ventricle.
- The right ventricle pumps blood through the pulmonary artery.
- The pulmonary artery carries blood to the lungs.
- The lungs add oxygen and remove carbon dioxide.
- Pulmonary veins carry blood from the lungs to the left atrium.
- The left atrium sends blood to the left ventricle.
- The left ventricle pumps blood into the aorta.
- The aorta carries blood to the body.

Cardiac Cycle

- Systole is when the heart contracts and pumps blood out.
- Diastole is when the heart relaxes and fills with blood.

Electrical Conduction

- The SA node is the heart's natural pacemaker.
- The AV node delays the electrical signal before the ventricles contract.

Remember: Right = lungs; left = body; systole = squeeze; diastole = relax.

5.4 — Blood Pressure

Pulse and Heart Rate

- A pulse is the expansion and recoil of an artery after the heart contracts.
- Each heartbeat produces one pulse.
- Pulse rate usually equals heart rate.
- A normal resting heart rate is 60–80 beats per minute.
- The radial artery can be used to measure pulse at the wrist.
- The carotid artery can be used to measure pulse at the neck.

Remember: One heartbeat = one pulse.

Blood Flow and Pressure

- Arteries have the highest blood pressure.
- Arteries have thick and elastic walls to handle high pressure.
- Capillaries have the slowest blood flow to allow exchange.
- Capillaries allow oxygen and nutrients to leave the blood.
- Capillaries allow carbon dioxide and wastes to enter the blood.
- Veins have the lowest blood pressure.
- Veins use valves to prevent blood from flowing backward.
- Skeletal muscles squeeze veins and help push blood toward the heart.
- Breathing helps draw blood back toward the heart through the respiratory pump.

Varicose Veins

- Varicose veins occur when vein valves become damaged.
- Damaged valves allow blood to pool and make veins swollen.

Remember: High pressure = arteries; slow exchange = capillaries; low pressure = veins.

Blood Pressure Numbers

- Blood pressure is measured in mm Hg.
- Normal blood pressure is about 120/80 mm Hg.
- Systolic pressure is the top number when the heart contracts.
- Diastolic pressure is the bottom number when the heart relaxes.
- Hypertension means blood pressure is too high.
- Hypertension can damage arteries over time.
- Hypertension increases the risk of heart attack, stroke, kidney disease, and aneurysm.
- Hypertension is called the silent killer because symptoms are often absent.

Remember: Systole = squeeze; diastole = down time.

5.5 — Two Cardiovascular Pathways

Pulmonary Circuit

- Pulmonary circulation moves blood from the heart to the lungs and back to the heart.
- The pulmonary circuit removes carbon dioxide from blood.
- The pulmonary circuit adds oxygen to blood.
- Pulmonary circulation has lower pressure and is shorter.

Systemic Circuit

- Systemic circulation moves blood from the heart to the body and back to the heart.
- The systemic circuit delivers oxygen and nutrients to the body.
- The systemic circuit removes carbon dioxide and wastes.
- Systemic circulation has higher pressure and is longer.

Remember: Pulmonary = lungs; systemic = body.

Major Arteries

- The aorta carries blood from the heart to the body.
- Pulmonary arteries carry blood from the heart to the lungs.
- Carotid arteries supply blood to the head and neck.
- Subclavian arteries supply blood to the upper body and arms.
- Renal arteries carry blood to the kidneys.
- Femoral arteries carry blood to the legs.

Major Veins

- The superior vena cava returns blood from the upper body to the heart.
- The inferior vena cava returns blood from the lower body to the heart.
- Pulmonary veins return oxygen-rich blood from the lungs to the heart.
- Jugular veins return blood from the head and neck.
- Renal veins carry blood away from the kidneys.
- Femoral veins return blood from the legs.

Oxygen Levels

- In systemic circulation, arteries usually carry oxygen-rich blood.
- In systemic circulation, veins usually carry oxygen-poor blood.
- Pulmonary arteries carry oxygen-poor blood.
- Pulmonary veins carry oxygen-rich blood.
- Blood vessels are named by the direction of blood flow rather than oxygen content.

Remember: Pulmonary artery = poor oxygen; pulmonary vein = plenty of oxygen.

Hepatic Portal System

- Blood from the digestive tract travels through the hepatic portal vein to the liver.
- The liver processes nutrients before blood returns to the heart.
- The hepatic vein carries blood from the liver to the inferior vena cava.
- The liver stores glucose as glycogen.
- The liver processes nutrients.
- The liver filters toxins.

- The liver produces blood proteins.

Remember: Gut → liver → heart.

5.6 — Exchange at the Capillaries

Blood Pressure

- Blood pressure pushes fluid out of capillaries through filtration.
- Water, oxygen, and nutrients move from blood into tissues.

Osmotic Pressure

- Plasma proteins such as albumin create osmotic pressure.
- Osmotic pressure pulls water back into capillaries.

Diffusion

- Oxygen and nutrients diffuse from blood into cells.
- Carbon dioxide and wastes diffuse from cells into blood.

Excess Tissue Fluid

- Not all fluid that leaves capillaries returns directly to the blood.
- Extra tissue fluid enters lymphatic vessels.
- Fluid inside lymphatic vessels is called lymph.
- Lymph eventually returns to the bloodstream through the subclavian veins.
- The lymphatic system prevents excess fluid from causing edema.

Remember: Blood pressure pushes out; osmotic pressure pulls in; lymph removes extra fluid.

CHAPTER 6 — BLOOD

6.1 — Blood: An Overview

What Is Blood?

- Blood is a liquid connective tissue that transports materials throughout the body.
- Blood delivers oxygen and nutrients to cells.

- Blood removes wastes from cells.
- Blood protects the body against disease.
- Blood helps maintain stable internal conditions called homeostasis.
- Plasma is the liquid part of blood.
- Formed elements are blood cells and cell fragments.

Remember: Blood = delivery system + protection system.

Functions of Blood

1. Transport

Oxygen

- Red blood cells carry oxygen using hemoglobin.
- Cells need oxygen to make ATP and produce energy.

Carbon Dioxide

- Cells produce carbon dioxide as a waste product when making energy.
- Blood carries carbon dioxide to the lungs for removal.

Nutrients

- Blood carries nutrients absorbed from digestion.
- Glucose provides energy for cells.
- Amino acids are used to build proteins.
- Vitamins and minerals support body functions.

Waste

- Blood carries waste products to organs that remove them.
- The kidneys remove urea from the blood and produce urine.

Hormones

- Hormones are chemical messages carried by blood from glands to target organs.

Remember: Blood delivers supplies and removes garbage.

2. Defense

- White blood cells protect the body from infection.
- Pathogens include bacteria, viruses, parasites, and fungi.

- Phagocytosis occurs when a white blood cell surrounds, eats, and destroys a pathogen.
- Antibodies are proteins made by lymphocytes that recognize specific pathogens.
- Platelets attach to damaged blood vessels and form a temporary plug.
- Fibrin strengthens the platelet plug into a stable clot.

Remember: Phagocytes eat invaders; antibodies identify enemies; platelets plug; fibrin strengthens.

3. Regulation

- Blood helps maintain homeostasis.
- Blood helps move heat around the body.
- Vasodilation widens blood vessels and allows more heat to leave the body.
- Vasoconstriction narrows blood vessels and helps keep heat inside the body.
- Plasma proteins help keep water inside blood vessels.
- Too much water leaving blood vessels can lower blood volume and blood pressure.
- Normal blood pH is about 7.4.
- Buffers prevent sudden changes in blood pH.

Remember: Dilate = lose heat; constrict = save heat.

Formed Elements of Blood

Red Blood Cells

- Red blood cells are also called erythrocytes.
- Red blood cells carry oxygen.
- Hemoglobin is the protein that binds oxygen.
- Hemoglobin contains iron.
- Red blood cells have no nucleus, leaving more space for hemoglobin.
- Red blood cells have a biconcave shape that improves gas exchange and flexibility.

Remember: RBCs are oxygen delivery trucks.

White Blood Cells

- White blood cells are also called leukocytes.
- White blood cells protect the body against infection.
- Neutrophils are the most common white blood cells.
- Neutrophils destroy bacteria through phagocytosis.
- Lymphocytes make antibodies and destroy infected cells.
- Monocytes become macrophages that eat pathogens and damaged tissue.

Platelets

- Platelets are also called thrombocytes.
- Platelets are fragments of large cells called megakaryocytes.
- Platelets help blood clot and repair damaged blood vessels.

Remember: Platelets repair leaks.

Plasma

- Plasma is the liquid portion of blood.
- Plasma makes up most of blood volume.
- Plasma carries blood cells, nutrients, hormones, wastes, and proteins.
- Water makes up about 91% of plasma.
- Albumin is the most common plasma protein.
- Albumin helps keep water inside blood vessels.
- Globulins help transport substances and include antibodies.
- Fibrinogen is a protein needed for blood clotting.
- Fibrinogen is converted into fibrin to strengthen blood clots.

Remember: Albumin holds water; globulin guards; fibrinogen forms the clot framework.

6.2 — Red Blood Cells and Transport of Gases

RBC Function

- Red blood cells transport oxygen from the lungs to body cells.
- Red blood cells transport carbon dioxide from body cells to the lungs.

Remember: RBCs are oxygen delivery trucks.

Hemoglobin

- Hemoglobin is a protein inside red blood cells.
- Hemoglobin gives blood its red colour.
- Globin is the protein portion of hemoglobin.
- Heme is the iron-containing portion of hemoglobin.
- Iron in heme binds oxygen.
- Hemoglobin combined with oxygen is called oxyhemoglobin.
- Hemoglobin without oxygen is called deoxyhemoglobin.

Remember: Heme holds oxygen.

Oxygen Transport

- Air enters the lungs and oxygen moves into the blood.
- Oxygen attaches to hemoglobin inside red blood cells.
- Blood carries oxygen to body tissues.
- Cells use oxygen to make ATP and energy.

Remember: Oxygen → ATP → energy.

Carbon Dioxide Transport

- Cells produce carbon dioxide as a waste product during energy production.
- Blood carries carbon dioxide back to the lungs.
- A small amount of carbon dioxide dissolves directly in plasma.
- Some carbon dioxide attaches to globin and forms carbaminohemoglobin.
- Most carbon dioxide is converted into bicarbonate ions.
- Carbonic anhydrase speeds up the conversion of carbon dioxide.

Remember: Carbonic anhydrase helps transport CO_2 safely.

RBC Adaptations

- The biconcave shape gives RBCs more surface area for gas movement.
- The biconcave shape also allows RBCs to squeeze through tiny capillaries.
- RBCs have no nucleus, leaving more room for hemoglobin.
- RBCs have no mitochondria, so they do not use the oxygen they carry.

RBC Lifespan

- Red blood cells live for about 120 days.
- The liver and spleen remove old red blood cells.
- Globin is broken down into reusable amino acids.
- Iron is reused to make new hemoglobin.
- Heme is converted into bilirubin and removed.

Erythropoietin

- Erythropoietin, or EPO, is a hormone produced by the kidneys.
- EPO stimulates the bone marrow to produce more red blood cells.
- Low oxygen levels cause the kidneys to release more EPO.
- More red blood cells allow more oxygen to be carried.
- High altitude can increase EPO production.

Remember: Low oxygen → EPO → more RBCs.

RBC Disorders

- Anemia occurs when blood cannot carry enough oxygen.
- Anemia can result from too few red blood cells or too little hemoglobin.
- Anemia can cause fatigue, weakness, and shortness of breath.
- Iron-deficiency anemia occurs when there is not enough iron to make hemoglobin.
- Sickle-cell disease is caused by a mutation that changes hemoglobin.
- Sickle-shaped RBCs can break easily and block blood vessels.

Remember: Anemia = not enough oxygen delivery.

6.3 — White Blood Cells and Defense Against Disease

Main Function

- White blood cells protect the body from bacteria, viruses, parasites, and abnormal cells.
- White blood cells are the immune system's soldiers.

WBC Characteristics

- White blood cells are larger than red blood cells.
- White blood cells have a nucleus.
- White blood cells do not contain hemoglobin.
- White blood cells are much less numerous than red blood cells.
- White blood cells are produced in red bone marrow.

Phagocytosis

- Phagocytosis occurs when white blood cells surround and destroy pathogens.
- Neutrophils and monocytes/macrophages perform phagocytosis.
- The WBC finds the pathogen, surrounds it, eats it, and destroys it.

Remember: Phagocytes eat invaders.

Antibodies

- Antibodies are proteins made by lymphocytes.
- Antibodies recognize specific pathogens.
- An antigen is a foreign substance that triggers an immune response.

- Lymphocytes recognize antigens and produce antibodies that attach to pathogens.

Remember: Antibodies tag enemies.

Types of WBCs

Neutrophils

- Neutrophils are the most common WBCs.
- Neutrophils are first responders that destroy bacteria.

Remember: Neutrophils = bacteria fighters.

Eosinophils

- Eosinophils fight parasites.
- Eosinophils are involved in allergies.

Remember: Eosinophils = parasites + allergies.

Basophils

- Basophils release histamine.
- Histamine helps cause inflammation.

Remember: Basophils = inflammation.

Lymphocytes

- B cells make antibodies.
- T cells destroy infected cells.

Remember: B = builds antibodies; T = terminates infected cells.

Monocytes

- Monocytes become macrophages.
- Macrophages eat pathogens and remove damaged cells.

Remember: Monocytes become cleanup crews.

WBC Disorders

- SCID occurs when the immune system does not develop properly.
- SCID causes a lack of working lymphocytes and severe infections.
- Leukemia is cancer of blood-forming tissues.
- Leukemia causes abnormal white blood cells to grow uncontrollably.

- Leukemia can reduce normal blood cell production.
- Infectious mononucleosis, or mono, is caused by the Epstein-Barr virus.
- Mono can cause fever, sore throat, fatigue, and swollen lymph nodes.

6.4 — Platelets and Blood Clotting

Why Clotting Matters

- Blood clotting prevents excessive blood loss.
- Blood clotting helps maintain blood volume and blood pressure.
- Blood clotting helps maintain homeostasis.

Remember: Clotting repairs leaks in blood vessels.

Platelets

- Platelets are also called thrombocytes.
- Platelets are fragments of megakaryocytes rather than complete cells.
- Platelets form the first plug after a blood vessel is injured.

Remember: Platelets are emergency repair workers.

Blood Clot Formation

- A damaged blood vessel causes platelets to attach to the injury.
- Attached platelets form a platelet plug.
- Prothrombin is converted into thrombin.
- Thrombin converts fibrinogen into fibrin.
- Fibrin traps blood cells and strengthens the clot.
- A stable clot forms over the damaged area.

Remember: Damage → platelets → thrombin → fibrin → clot.

Clotting Helpers

- Calcium is needed for clotting reactions.
- Vitamin K helps the liver produce clotting proteins.

Too Little Clotting

- Thrombocytopenia occurs when there are too few platelets.
- Thrombocytopenia can cause excessive bleeding.
- Hemophilia occurs when important clotting factors are missing.

- Hemophilia prevents fibrin clots from forming properly.
- von Willebrand disease occurs when platelets cannot stick properly.

Too Much Clotting

- A thrombus is a clot that forms inside an unbroken blood vessel.
- An embolus is a clot that breaks loose and travels through the blood.
- A thromboembolism occurs when a traveling clot blocks another blood vessel.

Remember: Thrombus = trapped; embolus = escaped.

6.5 — Human Blood Types

ABO Blood Types

- Blood types are determined by antigens found on red blood cells.
- The immune system attacks foreign antigens.

Remember: Antigens are ID tags on blood cells.

Type A

- Type A blood has A antigens and anti-B antibodies.

Type B

- Type B blood has B antigens and anti-A antibodies.

Type AB

- Type AB blood has A and B antigens but no anti-A or anti-B antibodies.

Type O

- Type O blood has no A or B antigens but has anti-A and anti-B antibodies.

Blood Compatibility

- Type O is the universal donor because it has no A or B antigens.
- Type AB is the universal recipient because it has no anti-A or anti-B antibodies.
- Agglutination occurs when incompatible blood types mix.
- Antibodies attack foreign antigens and cause red blood cells to clump together.

Remember: Wrong blood match = immune attack.

Rh Factor

- Rh-positive blood has the Rh antigen.
- Rh-negative blood does not have the Rh antigen.
- An Rh-negative mother carrying an Rh-positive baby can develop anti-Rh antibodies.
- Anti-Rh antibodies can destroy red blood cells in future Rh-positive babies.
- RhoGAM prevents the mother from forming these antibodies.

6.6 — Homeostasis and the Cardiovascular System

Homeostasis

- Homeostasis means keeping internal body conditions stable.
- The cardiovascular system maintains homeostasis by delivering oxygen and removing waste.
- The cardiovascular system transports hormones throughout the body.
- The cardiovascular system helps regulate body temperature.
- The cardiovascular system helps prevent blood loss.

Remember: The cardiovascular system keeps the body balanced.

Cardiovascular System

- The heart pumps blood.
- Blood vessels transport materials throughout the body.

Nervous System

- The nervous system controls heart rate.
- The nervous system controls blood vessel diameter.
- During exercise, the nervous system signals the heart to beat faster.

Endocrine System

- Hormones travel through the blood.
- Epinephrine increases heart rate during stress.
- EPO stimulates red blood cell production.

Respiratory System

- The respiratory system works with blood to exchange gases.
- The lungs add oxygen to the blood.

- The lungs remove carbon dioxide from the blood.
- Blood carries oxygen to cells.
- Blood carries carbon dioxide back to the lungs.

Muscular System

- Heart muscle pumps blood.
- Smooth muscle controls blood vessel diameter.
- Skeletal muscles help push blood through veins.

Skeletal System

- Red bone marrow produces red blood cells.
- Red bone marrow produces white blood cells.
- Red bone marrow produces platelets.
- Bones store calcium needed for blood clotting.

Digestive System

- The digestive system provides water and nutrients.
- The digestive system provides iron and vitamins.
- These nutrients are needed for red blood cell production and plasma proteins.

Urinary System

- The kidneys remove waste from the blood.
- The kidneys control water and salt balance.
- The kidneys produce EPO.

Lymphatic System

- The lymphatic system returns extra tissue fluid to the blood.
- The lymphatic system helps maintain blood volume.

Chapter 6 Big Picture

- Blood transports oxygen, nutrients, hormones, and wastes.
- Blood defends the body against infection and blood loss.
- Blood regulates temperature, pH, and fluid balance.
- Blood is the body's transportation, defense, and balance system that maintains homeostasis.

WEEK 5 — CHAPTER 11: URINARY SYSTEM

11.1 — Overview of the Urinary System

Main Idea

- The urinary system maintains homeostasis by cleaning the blood and balancing important substances.

Main Functions

- The urinary system removes wastes made by cells.
- The urinary system controls the amount of water in the body.
- The urinary system balances electrolytes such as sodium, potassium, calcium, and chloride.
- The urinary system maintains blood pH between about 7.35 and 7.45.
- The urinary system helps regulate blood pressure by controlling blood volume and salt levels.
- The urinary system produces hormones that help make red blood cells and maintain bones.

Remember: Kidneys = clean, balance, save.

Organs of the Urinary System

Kidneys

- The kidneys filter blood and make urine.
- The kidneys remove wastes such as urea, creatinine, and uric acid.
- The kidneys control water and salt levels.
- The kidneys maintain blood pH.
- The kidneys help control blood pressure.
- Renin helps increase blood pressure.
- EPO stimulates red blood cell production.
- Activated vitamin D helps the body absorb calcium for bones.
- The kidneys are two bean-shaped organs located near the lower back below the ribs.

Ureters

- Ureters transport urine from the kidneys to the bladder.
- Ureters are muscular tubes.

- Ureters use peristalsis to push urine toward the bladder.
- Ureters do not filter or store urine.

Urinary Bladder

- The bladder stores urine until it leaves the body.
- The bladder is a stretchable muscular organ.
- The bladder can hold about 700–800 mL.
- Transitional epithelium allows the bladder to expand.
- The internal sphincter is smooth muscle under involuntary control.
- The external sphincter is skeletal muscle under voluntary control.

Urethra

- The urethra carries urine out of the body.
- The female urethra is shorter and therefore has a higher chance of UTIs.
- The male urethra is longer and carries urine and semen at different times.

Kidney Structure

Renal Cortex

- The renal cortex is the outer layer of the kidney.
- The renal cortex is where blood filtration begins.
- The renal cortex contains glomeruli, PCTs, and DCTs.

Remember: Cortex = cleaning starts here.

Renal Medulla

- The renal medulla is the inner layer of the kidney.
- The renal medulla helps control water balance and concentrate urine.
- The renal medulla contains the loops of Henle and collecting ducts.
- When dehydrated, the kidneys keep more water and produce darker urine.
- When hydrated, the kidneys remove more water and produce lighter urine.

Remember: Medulla = water saver.

Renal Pelvis

- The renal pelvis collects urine before it enters the ureter.
- Urine travels from the collecting duct to the renal pelvis, ureter, and bladder.

Nephron Structure

What Is a Nephron?

- The nephron is the functional unit of the kidney.
- The nephron is the smallest structure that performs kidney functions.
- The nephron filters blood and creates urine.
- Each kidney contains about one million nephrons.

Glomerulus

- The glomerulus filters blood using high pressure.
- Small molecules such as water, glucose, salts, and urea can pass through.
- Blood cells and large proteins normally stay in the blood.

Remember: Glomerulus = filter.

Bowman's Capsule

- Bowman's capsule collects the filtered fluid from the glomerulus.

Remember: Bowman's capsule = collecting bowl.

Proximal Convoluted Tubule

- The PCT reabsorbs most useful substances back into the blood.
- The PCT reabsorbs glucose, amino acids, sodium, water, and bicarbonate.
- The PCT has many microvilli that increase surface area.
- The PCT has many mitochondria that provide energy for reabsorption.

Loop of Henle

- The loop of Henle controls water and salt balance.
- Water leaves the descending limb.
- Salt leaves the ascending limb.
- Water stays inside the ascending limb.
- The loop of Henle helps create concentrated urine.

Distal Convoluted Tubule

- The DCT makes final adjustments to the filtrate.
- The DCT helps control sodium, potassium, and calcium.

- Aldosterone and parathyroid hormone control some DCT functions.

Collecting Duct

- The collecting duct determines the final concentration of urine.
- ADH controls how much water is reabsorbed in the collecting duct.
- ADH causes more water to be saved and less concentrated urine to be produced.
- Without ADH, less water is saved and more urine is produced.

11.2 — Urine Formation

Three Main Steps

- Urine formation involves filtration, reabsorption, and secretion.

Remember: FRS = Filter → Reabsorb → Secrete.

Filtration

- Filtration occurs in the glomerulus when blood pressure pushes small substances into the nephron.
- Water, glucose, amino acids, salts, and urea are filtered.
- Blood cells and proteins normally remain in the blood.

Reabsorption

- Reabsorption returns useful substances from the nephron back into the blood.
- The kidneys reabsorb almost all glucose and amino acids.
- The kidneys reabsorb most water and sodium.
- About 99% of filtered water returns to the blood.

Secretion

- Secretion moves extra wastes from the blood into the nephron.
- The kidneys secrete hydrogen ions, creatinine, drugs, toxins, and ammonium.
- Secretion helps remove waste and control blood pH.

Excretion

- Excretion occurs when the remaining fluid leaves the body as urine.
- Urine travels from the kidney to the ureter, bladder, urethra, and outside the body.

11.3 — Kidneys and Homeostasis

Water and Salt Balance

- The kidneys constantly adjust water, sodium, potassium, and other electrolytes.
- Water follows salt.
- More sodium in the blood causes more water to be retained.
- More water retention increases blood volume and blood pressure.
- Less sodium causes less water retention.
- Less water retention decreases blood volume and blood pressure.

ADH

- ADH saves water when the body is dehydrated.
- ADH is released when the blood is too concentrated.
- ADH adds water channels to collecting ducts.
- ADH causes more water to return to the blood.
- ADH causes less, darker, and more concentrated urine.
- ADH increases blood volume.

Remember: ADH = adds water back.

Aldosterone

- Aldosterone saves sodium when blood pressure or sodium levels are low.
- Aldosterone increases sodium reabsorption.
- Aldosterone increases potassium removal.
- Water follows sodium back into the blood.
- Aldosterone increases blood volume and blood pressure.

Remember: Aldosterone = adds salt.

Renin

- Renin starts the system that raises blood pressure.
- The kidneys release renin when blood pressure or kidney blood flow decreases.
- Renin activates the RAAS.
- RAAS causes aldosterone release.
- Aldosterone causes more sodium and water to be saved.
- Saving sodium and water increases blood pressure.

Remember: Low BP → renin → RAAS → aldosterone → more water → higher BP.

ANH/ANP

- ANH/ANP lowers blood pressure when blood volume is too high.
- ANH/ANP causes sodium and water to be removed.
- Removing sodium and water decreases blood volume.
- Lower blood volume decreases blood pressure.

Blood pH Regulation

- Normal blood pH is 7.35–7.45.
- When blood is too acidic, the kidneys remove hydrogen ions.
- When blood is too acidic, the kidneys keep bicarbonate.
- Removing hydrogen ions and keeping bicarbonate raises blood pH.
- When blood is too basic, the kidneys keep hydrogen ions.
- When blood is too basic, the kidneys remove bicarbonate.
- These actions help return blood pH toward normal.

11.4 — Urinary System Disorders

Urethritis

- Urethritis is an infection of the urethra.
- Urethritis can cause burning, pain, and frequent urination.

Cystitis

- Cystitis is an infection of the bladder.
- Cystitis can cause burning, frequent urination, and lower abdominal pain.

Pyelonephritis

- Pyelonephritis is a kidney infection.
- Pyelonephritis often begins as a bladder infection that spreads to the kidneys.
- Symptoms can include fever, back pain, nausea, and vomiting.

Kidney Stones

- Kidney stones are hard crystals made from minerals.
- Kidney stones can block urine flow.
- Kidney stones can cause severe pain, blood in the urine, and difficulty urinating.

Uremia

- Uremia occurs when the kidneys cannot remove enough urea.
- Uremia causes waste to build up in the blood.
- Severe uremia can become dangerous.

Edema

- Edema is swelling caused by too much fluid in tissues.
- Edema can occur when the kidneys cannot remove enough water and salt.

Benign Prostatic Hyperplasia

- BPH is an enlarged prostate in males.
- An enlarged prostate can squeeze the urethra and make urination difficult.
- BPH can cause a weak urine stream, frequent urination, and difficulty starting urination.

Dialysis

Why Dialysis Is Needed

- Dialysis is needed when the kidneys cannot properly filter the blood.
- Kidney failure causes wastes to build up in the blood.
- Kidney failure causes problems with water balance.
- Kidney failure can cause abnormal blood pH.
- Kidney failure can cause electrolyte imbalances.
- Dialysis temporarily replaces kidney filtration.

Hemodialysis

- Hemodialysis removes blood from the body and passes it through a machine.
- Hemodialysis removes urea, creatinine, extra water, and extra salts.
- Hemodialysis helps restore pH, fluid balance, and electrolyte balance.
- Dialysis must be repeated because healthy kidneys work continuously.
- Waste continues to be produced after dialysis, so treatments must happen regularly.

FINAL EXAM MEMORY SUMMARY

Kidney → Nephron → Urine

- The glomerulus filters the blood.
- The PCT reabsorbs useful substances.
- The loop of Henle controls water and salt balance.
- The DCT makes final adjustments.
- The collecting duct controls final water reabsorption using ADH.
- The remaining fluid becomes urine and leaves the body.

Hormones

- ADH saves water.
- Aldosterone saves sodium.
- Renin raises blood pressure by starting RAAS.
- ANH lowers blood pressure.
- EPO stimulates red blood cell production.
- Activated vitamin D helps the body absorb calcium for bones.

Main Idea

- The urinary system keeps the body balanced by filtering blood, saving useful substances, removing waste, and controlling water, salts, pH, and blood pressure.

CHAPTER 7 —
7.1 — THE LYMPHATIC SYSTEM
Main Functions

- The lymphatic system helps maintain fluid balance in the body.
- Lymphatic capillaries collect extra fluid from tissues and return it to the blood.
- Lymphatic capillaries absorb fats from the digestive tract and transport them to the blood.
- Lymphatic organs help protect the body from disease.

Lymph

- Lymph is the fluid found inside lymphatic vessels.
- Lymph mainly comes from interstitial fluid.
- Interstitial fluid contains water, nutrients, electrolytes, oxygen, hormones, enzymes, and wastes.
- Lymphatic vessels move lymph in one direction toward the cardiovascular system.
- Lymphatic vessels have valves that prevent lymph from flowing backward.

Lymphatic Organs

- Red bone marrow produces all types of blood cells.
- B cells mature in the red bone marrow.
- The thymus is where T cells mature.
- The spleen filters blood and removes cellular debris and bacteria.
- Lymph nodes filter lymph and help detect pathogens.
- Tonsils help prevent pathogens from entering through the nose and mouth.
- The appendix and other tissues contain lymphatic tissue that helps defend the body.

- The thoracic duct returns lymph to the left subclavian vein.
- The right lymphatic duct returns lymph to the right subclavian vein.

Primary Lymphatic Organs

- The primary lymphatic organs are the red bone marrow and thymus.
- Red bone marrow is where blood cells are produced and B cells mature.
- The thymus is where T cells mature.

Secondary Lymphatic Organs

- The secondary lymphatic organs include the spleen, lymph nodes, and tonsils.
- The spleen cleans the blood of pathogens and debris.
- Lymph nodes clean lymph of pathogens and debris.

7.2 — INNATE IMMUNE DEFENSES

Innate Immunity

- Innate immunity is the body's first defense against pathogens.
- Innate defenses work quickly without previous exposure to a pathogen.
- Innate immunity does not create immune memory.

Physical and Chemical Barriers

- The skin acts as a physical barrier that prevents pathogens from entering the body.
- Skin oils create chemicals that can weaken or kill some bacteria.
- Mucous membranes trap pathogens before they enter deeper tissues.
- Cilia move mucus and trapped particles out of the respiratory tract.
- Tears, saliva, and sweat contain lysozyme that can destroy bacteria.
- Urine helps flush bacteria out of the urinary tract.
- Stomach acid kills or prevents the growth of many bacteria.
- Normal flora are helpful bacteria that prevent harmful pathogens from taking over.

Inflammatory Response

- Inflammation is the second line of defense against pathogens entering damaged tissue.
- Inflammation causes redness, heat, swelling, and pain.
- Damaged cells and mast cells release histamine.
- Histamine causes blood vessels to widen and increases blood flow.
- Macrophages and dendritic cells engulf pathogens and release cytokines.
- Neutrophils and monocytes move into the damaged tissue.
- Monocytes become macrophages that destroy pathogens.
- Phagocytes destroy pathogens by engulfing them through phagocytosis.
- Blood clotting helps seal damaged tissue and prevent blood loss.

Natural Killer Cells

- Natural killer cells destroy abnormal cells such as infected or cancerous cells.
- Natural killer cells are part of the innate immune system.

Complement Proteins

- Complement proteins are protective proteins found in the blood.
- Complement proteins help destroy pathogens.
- Complement proteins can help immune cells recognize and attack pathogens.

Interferons

- Interferons are proteins released by virus-infected cells.
- Interferons warn nearby cells about a viral infection.
- Interferons cause nearby cells to produce substances that slow viral replication.

Remember: Innate = fast, general, and no memory.

7.3 — ADAPTIVE IMMUNE DEFENSES

Adaptive Immunity

- Adaptive immunity develops when innate defenses cannot stop an infection.
- Adaptive immunity specifically targets the pathogen causing the infection.
- Adaptive immunity creates memory so the body can respond faster the next time.
- Adaptive immunity can also help protect against cancer.
- Adaptive immunity depends mainly on B cells and T cells.

Antigens

- An antigen is a foreign substance that the immune system recognizes.
- Antigens can be found on bacteria, viruses, fungi, parasites, and cancer cells.
- The immune system normally recognizes the body's own cells as self.
- The immune system attacks foreign substances as nonself.

B Cells

- B cells recognize specific antigens using B-cell receptors.
- An activated B cell undergoes clonal expansion.
- Clonal expansion produces many copies of the activated B cell.
- Most cloned B cells become plasma cells.
- Plasma cells produce antibodies against the specific antigen.
- Some cloned B cells become memory B cells.
- Memory B cells remain in the body and provide long-term protection.
- Memory B cells quickly produce plasma cells if the same antigen appears again.

Antibodies

- Antibodies are proteins produced by plasma cells.
- Antibodies bind to specific antigens.
- Antibodies can neutralize pathogens and toxins.
- Antibodies can cause pathogens to clump together.
- Antibodies can attract white blood cells to the pathogen.

Main Antibody Types

- IgG is the main antibody found in the blood.
- IgG can cross the placenta and provide temporary protection to a fetus.
- IgM is the first antibody produced during an immune response.
- IgM strongly activates the complement system.
- IgA is found mainly in body secretions such as saliva, tears, mucus, and breast milk.
- IgA helps prevent pathogens from entering the bloodstream.

Remember: B cells → plasma cells → antibodies.

T CELLS

T Cell Development

- T cells are produced in the bone marrow.
- T cells mature in the thymus.
- T cells recognize specific antigens using T-cell receptors.

Cytotoxic T Cells

- Cytotoxic T cells destroy virus-infected cells and cancer cells.
- Cytotoxic T cells release perforin that makes holes in target cells.
- Cytotoxic T cells release granzymes that enter the holes and cause cell death.
- Cytotoxic T cells are responsible for cell-mediated immunity.

Helper T Cells

- Helper T cells control immune responses by releasing cytokines.
- Cytokines help activate and regulate other immune cells.
- B cells require help from helper T cells to become fully activated.

Memory T Cells

- Some activated T cells become memory T cells.
- Memory T cells remain in the body after an infection ends.
- Memory T cells allow a faster response if the same antigen returns.

Remember: Cytotoxic T = kills; Helper T = helps; Memory T = remembers.

7.4 — ACQUIRED IMMUNITY

Active Immunity

- Active immunity occurs when your own immune system produces antibodies.
- Active immunity can develop naturally after an infection.
- Active immunity can also develop artificially through vaccination.
- Active immunity is usually long-lasting because memory B and T cells remain.
- A booster may sometimes be needed to strengthen active immunity.

Vaccines

- Vaccines expose the immune system to an antigen without causing the full disease.
- Vaccines stimulate the body to produce an immune response.
- The first vaccine exposure creates a primary immune response.
- The first immune response produces antibodies slowly.
- Memory cells remain after the first exposure.
- A second exposure creates a faster and stronger secondary response.
- A booster is a later exposure that increases antibody levels.

Passive Immunity

- Passive immunity occurs when a person receives antibodies made by someone or something else.
- Passive immunity does not require the person's immune system to make the antibodies.
- Passive immunity is temporary because memory cells are not produced.
- A fetus can receive IgG antibodies from the mother through the placenta.
- A baby can receive IgG and IgA antibodies through breast milk.
- Passive immunity can also be given through an antibody injection.

Remember: Active = you make antibodies; passive = you receive antibodies.

7.5 — DISORDERS OF THE IMMUNE SYSTEM

HIV and AIDS

- HIV is the virus that causes AIDS.
- HIV mainly infects and destroys helper T cells and other immune cells.
- Losing helper T cells weakens the body's immune response.
- AIDS is the advanced stage of HIV infection.
- AIDS causes severe weakening of the immune system.
- Opportunistic infections occur because the weakened immune system cannot fight them effectively.

Opportunistic Infections

- Opportunistic infections are infections that take advantage of a weakened immune system.
- Candidiasis is a yeast infection that can occur when immunity is weakened.
- Pneumocystis pneumonia is a fungal infection that can occur with severe immune suppression.
- Kaposi sarcoma is a cancer associated with weakened immunity.
- Cytomegalovirus can cause serious disease when immunity is severely weakened.

Allergies

- An allergy is an excessive immune response to a normally harmless substance.
- Substances that trigger allergies are called allergens.
- Common allergens include pollen, food, and animal hair.
- IgE antibodies are involved in immediate allergic reactions.
- IgE antibodies attach to mast cells and basophils.
- When an allergen binds to IgE, mast cells and basophils release chemicals that cause symptoms.

Autoimmune Diseases

- An autoimmune disease occurs when the immune system attacks the body's own cells.
- The immune system normally distinguishes self from nonself.
- Autoimmune disease occurs when this self-recognition fails.
- Rheumatoid arthritis is an autoimmune disease that causes inflammation and damage in joints.
- Autoimmune diseases can involve both B cells and T cells.